The Mathematics Education into the 21st Century Project
Proceedings of the International Conference
The Decidable and the Undecidable in Mathematics Education
Brno, Czech Republic, September 2003

A model for professional development for graphics calculator use

Barry Kissane
School of Education, Murdoch University, Australia, kissane@murdoch.edu.au

Abstract: A key component of any kind of mathematics curriculum change is the development of professional expertise among teachers. This paper offers an outline model of the stages through which mathematics teachers seem to pass when learning to integrate a graphics calculator into their professional practice. The model describes four developmental stages of progression: (1) Where's the ON button? (2) Black line mastery; (3) Routine use; and (4) Curriculum change. For each stage identified, the characteristics of teacher activity are described, together with an analysis of the professional development needs characteristic of the stage. The paper concludes with some consideration of ways in which the model might be used to guide professional support programs and to understand typical problems associated with the integration of technology into the regular mathematics curriculum.

Few would doubt that technology is a major influence on the mathematics curriculum today and into the foreseeable future. For mathematics education, many modern technologies have been developed and considered for educational use. However, this paper concentrates attention on the particular technology of the graphics calculator, arguably the only form of technology developed particularly for school mathematics education. The significance of graphics calculators for mathematics education rests in no small part on their accessibility, a function of their physical size, price relative to other technologies and ready portability from one educational setting to another. (Kissane, 1995). These characteristics together make it much more likely that the personal technology of the graphics calculator will be available for mathematics teachers to use and hence much more likely that technology can be regarded as relevant to curriculum development in mathematics.

Availability of technology is not by itself adequate, of course, to effect changes in the mathematics curriculum. A crucial mediating factor is the teacher, and curriculum developers ignore the real needs of teachers at their peril (Kissane, 2002). Mathematics teachers need professional development directly related to graphics calculators if they are to be the main agents of reform, and ultimately directly responsible for whatever happens in the classroom. It is already clear in those countries where this sort of technology has been available for some time that sound integration of the technology into the curriculum does not come about by chance alone.

This paper offers a tentative theoretical model for thinking about the various stages through which mathematics teachers progress in order to incorporate the technology appropriately into their practice. The model describes four identifiable stages, based mostly on the author's experiences of being involved in activity of this kind over the past decade. It is proposed that the key features of each stage are identifiably different, and that care is needed to recognise the stage of development in which teachers are located in order to plan professional development accordingly. Outcomes to be attained at the end of each of the first three stages are identified, and it is suggested that these provide a signal that movement has taken place from stage to stage. The model rests on the author's belief that technology ought be integrated into the curriculum, rather than being regarded as an optional extra, so that it is a key element in the everyday practice of teachers and their pupils and is adequately taken into account when curricula are devised or developed.

To date, empirical data have not been formally collected in order to validate the model, although it does rest in part on various professional conversations over at least the past decade about the needs of teachers in relation to graphics calculators. It seems important to explicate and develop a theory before it is tested empirically, however.

Table 1 offers a brief summary of the model, which is described in a little more detail in the remainder of the paper, followed by some suggestion for its use and further development.

Table 1: A summary of the model

Stage	Outcome	Teacher activity	Professional Development
1 **Where's the ON Button?**	The teacher has the technical skill to undertake confidently and independently graphics calculator tasks relevant to the mathematics they teach	Calculator skills Use of calculator for own purposes Investigating calculator capabilities	Hands-on workshops Peer collaboration Less emphasis on class use; more emphasis on individual use Common pitfalls Published beginner guides
2 **Black Line Mastery**	The teacher manages pupil use of graphics calculators for particular tasks in the existing curriculum	Using calculator in classroom Lessons developed by others Black Line Masters Class sets of calculators Use of OHP	Advice from practitioners Targetted on local curriculum More emphasis on classroom use Specific management advice Published resource materials
3 **Routine Use**	In developing lessons, the teacher routinely considers possible uses of a graphics calculator for pupil learning and plans accordingly	Everyday classroom use Part of all lesson planning Pupil ownership Learned discretionary use	Conversations between peers Teacher conferences Refinement of practice Developing new uses
4 **What's in the Curriculum?**		Pushing curriculum boundaries Additions and deletions of curriculum topics	Peer collaboration Official curriculum development Professional writing and reading

Stage One: Where's the ON button?

Graphics calculators are rather more complicated than their predecessors (scientific calculators) and can be rather daunting for novices to use. Although all graphics calculators come equipped with a manual of instructions of some kind, the task of navigating one's way around the calculator can seem an overwhelming one to some teachers, especially those lacking in confidence and a spirit of adventure. The characterisation of this first stage of development as 'Where's the ON button?' reflects the major activity of finding which calculator buttons activate which particular operations. Many persons engaged in providing professional development support for teachers in Australia have referred to the initial stage in these terms, providing some anecdotal support for its existence.

Teacher activity

In this stage, the teacher is mostly concerned with learning how to use the calculator for their own purposes. This involves developing confidence to undertake particular tasks such as those to do with accessing and using multiple perspectives of functions, analysing a set of data from both a graphical and numerical perspective and representing and solving a set of simultaneous linear equations. Although these tasks are likely to be of widespread interest to mathematics teachers, there are some others that are mostly of interest to those with particular curriculum responsibilities. Examples include the use of calculators to handle numerical aspects of the calculus, matrix manipulation or financial mathematics. To an extent, work in this stage is concerned with finding out what kinds of things calculators are capable of doing, especially since many novices seem to regard graphics calculators as mostly of value for dealing with graphs, a misconception that is soon rendered clear after some experience.

Professional development

Professional development at this stage is directed towards achievement of the outcome:
The teacher has the technical skill to undertake confidently and independently graphics calculator tasks relevant to the mathematics they teach.

The focus here is on helping the teacher to understand what graphics calculators are capable of doing and how to use them for that purpose confidently and efficiently. An emphasis on the technical skill associated with operating the calculator suggests that it is easiest if only a single calculator model is used. Hands-on workshops provide the best form of professional development here, with at least one calculator being available for each pair of teachers. Indeed, some regard it is better for beginners to work with a single calculator between two people, to allow fruitful peer discussion and to share some of the inevitable problems that arise in practice. It is important that persons conducting this form of professional development are able to understand how bewildering a new and complex piece of technology might seem to a novice, and are thus prepared to go as slowly as necessary. While it is tempting to help teachers at this stage by providing extensive written keystrokes to follow, this may be of illusory help, as the focus can quickly become button finding and pushing, rather than understanding how and why the keystrokes have the intended effects.

It is not necessarily helpful at this stage to focus much attention at all on the educational uses of the technology, as the main aim is to make sure that teachers themselves are comfortable using it. The premise for this advice is that teachers seem unlikely to be willing to make use in their classrooms of a technology that they do not yet feel personally comfortable with. Indeed, it is worthwhile at this stage to highlight some of the likely pitfalls of beginners (especially if they do not arise naturally), so that teachers will begin to develop some confidence that they will be able to deal with problems their own pupils encounter.

In the event that a hands-on workshop is not available, teachers at this stage can learn a good deal from personal experimenting, especially if they have access to more experienced colleagues. Written materials intended to help teachers at this stage, such as Kissane & Harradine (2001), may be useful in the event of workshop support being unavailable. It is also helpful to have short summaries of major calculator operations available, such as those in Kissane (2003). In addition, the exercise sets in Kissane (2003) are examples of tasks designed to help teachers attain Stage One competence.

Once Stage One outcome has been attained, attention might shift to the second stage, described next.

Stage Two: Black Line Mastery

In contrast with the first stage, the second stage concerns the use of graphics calculators in the mathematics classroom. It takes some courage for a teacher to move from personal use of the calculator to supervising its use in the classroom by their pupils. The term 'Black Line Master' is currently used in some countries to denote a reproducible activity sheet, intended for pupil use, most likely with corresponding advice available for the teacher. A focus at this stage is on a teacher making effective use of activities and materials developed and trialled by others, rather than developing their own ways of integrating the calculator into the curriculum.

Teacher activity

During this stage, special calculator lessons are planned, in which successful deployment of a calculator is a key aspect. Teachers and their pupils may even regard them as 'calculator lessons', since the use of the graphics calculator may still be something of a novelty at this stage. The teacher may rely on using a class set of graphics calculators for particular lessons, and remain unconcerned that pupils do not have their own calculators for regular use.

There is a preference here for ideas that others have tried out successfully, since there is an associated reassurance that the lessons will 'work'. In this context, decisions about the success of a lesson may be dominated by evidence that pupils have managed the tasks successfully on their calculators and have found the experience engaging to some extent. Black Line Masters or similar materials are judged to be valuable if they are thought by pupils to be interesting and if the instructions are clear. As part of their preparation for lessons using calculators, teachers are likely to work through the chosen activities themselves, anticipating likely problems pupils might have operating their calculators successfully. In the classroom, an overhead projector model of the graphics calculator may be used to make sure that pupils can successfully complete the work expected of them and to illustrate any difficult calculator operation steps.

In some instances, this stage may also have an assessment overtone, especially in those settings in which graphics calculators are permitted for use in high stakes examinations external to the school. There is a considerable premium in such settings on making sure that pupils can use their calculators efficiently to complete examination tasks.

Professional development

Professional development at this stage is directed towards achievement of the outcome:

The teacher manages pupil use of graphics calculators for particular tasks in the existing curriculum.

There is a focus on the provision and elaboration of suitable pupil activities that exploit the capabilities of the graphics calculator, usually in a controlled way. Thus, an activity concerned with the use of graphics calculators to explore the effects of transformations on functions may have specific examples chosen for the pupils and even particular viewing window settings recommended to make sure that all the necessary graphs can be seen at the same time. The use of calculator screen dumps may be a convenient way to make sure that pupil use of the calculator follows the predetermined paths. Teachers will of course prefer that the activities used to concentrate professional development are relevant to their particular curriculum setting, so that materials accessed via the Internet or from books published in other states or countries may be less attractive than would otherwise be the case.

Much of the professional development relevant to this stage consists of well-crafted advice from classroom experts for relative novices. Teachers want and need ideas from other practitioners that will work in their own classroom, with minimal risks of problems arising. In addition, advice is needed on how best to manage the classroom activity, avoiding any known calculator pitfalls (such as pupils forgetting to change their calculator from degrees to radians). This stage might be characterised also by resource dissemination, as it is especially relevant to teachers sharing their good ideas with each other, either in print or via the Internet, in sufficient detail for others to make easy use of them. Good examples include the *Mathematical Interactions* series (Kissane & Harradine, 2000) and the collection of teacher lessons compiled by Harradine, Kissane & O'Brien (2002).

Stage Three: Routine use

This stage of development also is concerned with educational uses of graphics calculators, but the focus now shifts from using the ideas of others to developing one's own ideas. Teachers at this stage of development have come to regard the graphics calculator as a routine item of classroom equipment, regularly used by their pupils and most probably personally owned by their pupils.

Teacher activity

This stage is characterised by the graphics calculator having become a routine part of the classroom and the teacher's thinking. All lessons are planned on the assumption that graphics calculators are available and will be used where they are found to be helpful for pupil learning. Although it is likely that pupils have their own graphics calculator, the teacher is quite comfortable with the idea that the calculators are not helpful for some learning purposes and are not concerned when pupils are not using them. The calculator has lost the novelty status characteristic of the first two stages and is regarded as an instrument for learning as well as a tool for mathematical work. Classroom work planned by the teacher is more likely to include pupil exploration and investigation using the calculator, with tasks like those described as 'activities' in Kissane (2003).

The teacher may also at this stage focus some attention on learned discretionary use of the calculator, expecting pupils to decide for themselves when and when not to make use of a calculator, and providing classroom time and opportunities to discuss the pupils' decisions about these. The teacher is thus quite comfortable with a classroom in which not all pupils are using their calculators at the same time and in the same ways. An overhead projector model of a calculator has become a regular classroom tool for engaging the class in discussions of issues that have arisen through the agency of the graphics calculator. Pupils may be expected to use the overhead model as well as teachers.

Professional development

Professional development at this stage is directed towards achievement of the outcome:

> *In developing lessons, the teacher routinely considers possible uses of a graphics calculator for pupil learning and plans accordingly.*

A key aspect of professional development at this stage involves conversations between experienced peers about the mathematics that pupils are learning. Rather than regarding colleagues as a source of good ideas to borrow, teachers at this stage regard them as peers with whom to discuss problems of practice that have arisen in the context of a classroom with graphics calculators regularly available. As well as success stories, professional conversations here identify problems encountered by pupils and their possible resolution.

Professional development contexts here may include sessions at teacher conferences or professional writing in teacher journals, as well as the casual meeting of colleagues within a school. The focus has shifted from using graphics calculators 'successfully' in the classroom and 'efficiently' for assessment, to increasing the likelihood that pupils will learn important mathematical concepts and develop key mathematical skills. In addition, professional development may focus to an extent on pushing the boundaries of the technology, exploiting lesser-known features (such as programming and using data loggers) and on innovative and unexpected uses of graphics calculators.

Stage Four: What's in the curriculum?

This final stage shifts the emphasis away from the classroom and on to the mathematics curriculum as a whole. Rather than regarding the curriculum as relatively fixed and the graphics calculator as an agent for successfully implementing it, the calculator is here regarded as an instrument for curriculum development and even school change. The significance of pupils having regular and unfettered access to personal technology is that some elements of the curriculum become more contestable.

Teacher activity

Having attained the outcome identified in Stage Three, the teacher at this stage is beginning to question the status of some elements of the curriculum in the light of the opportunities provided by graphics calculators and is starting to explore these with their pupils. For example, the focus of elementary algebra curricula on the exact solutions of equations is questioned, in the light of the many numerical alternatives offered through graphics calculators. In addition, the development of algebraic calculators with CAS capabilities provides an environment in which the focus of the present algebra curriculum becomes open to question from teachers.

Not only are curriculum deletions considered, but some elements of mathematical activity presently absent from school curricula are given serious consideration because of the capabilities afforded by graphics calculators. An example of this is the use of calculators to engage in simulations or to explore current mathematical topics such as chaos theory. The teacher in this stage is characterised as a thinking professional, re-evaluating the mathematics curriculum and even the nature of mathematics itself, in the light of the personal technology in the hands of their pupils, rather than relying on others to undertake re-evaluations of this kind.

Professional development

The professional development needs of teachers at this stage focus on opportunities for peer collaboration and for classroom experimentation. Professional conferences and publications are of key importance, as are the opportunities to explore the boundaries of mathematics and technology with their pupils. Teachers at this stage may be involved in the provision of professional development for others and in state-level work in reconceptualizing the school mathematics curriculum to accommodate the challenges and opportunities of available technology.

Some implications and conclusions

Realistically, teachers have many pressures for change and personal growth, so that it is unlikely that attention can be devoted to this arena alone. Experience to date suggests that the four stages described here are likely to characterise teacher progression with graphics calculators over an extended period of time; years rather than months are more likely to be the relevant units in many cases. Validation of this observation, and of the model itself, requires data to be collected more systematically from the field than has been done to date, however.

Stimulus for professional development related to technological change can come from many sources, including mandated curriculum change, official examination changes, personal curiosity, professional contacts, professional reading and so on. While some professional development may be provided by central agencies and employers, and some by calculator companies, it seems likely that teachers themselves may have important roles to play in the provision of professional development for other teachers at lower stages than themselves.

Teachers offered professional development opportunities prematurely may find them less helpful than would otherwise be expected. This seems especially so for Stage 2, which is likely to be most important to teachers who have progressed beyond Stage 1, but potentially confusing for those who have not yet done so. Again, data on such questions ought to be sought.

References

Harradine, A., B. Kissane & G. O'Brien (eds) 2002. *Enhancing mathematics learning with a graphics calculator*, Shriro, Sydney.

Kissane, B. 1995. The importance of being accessible: The graphics calculator in mathematics education. In *First Asian Conference on Technology in Mathematics* (pp 161-170), The Association of Mathematics Educators, Singapore.

Kissane, B. 2002. Technology and the curriculum: The case of the graphics calculator. *New Zealand Mathematics Magazine*, 39, 1, 64-84.

Kissane, B. 2003. *Mathematics with a graphics calculator: Casio cfx-9850GB PLUS*, Perth: Mathematical Association of Western Australia.

Kissane, B. & A. Harradine 2000. *Mathematical Interactions series*, Shriro, Sydney.

Kissane, B. & A. Harradine 2001. *Getting Started*, Shriro, Sydney.